RELAX NG: DTDs ON WARP DRIVE

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Reuter Health Information
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Abstract

In this tutorial you will learn how to use the RELAX NG schema language, an alternative schema language for XML. RELAX NG allows easy and intuitive descriptions of just what is and what is not allowed in an XML document. It is simple enough to learn in a few hours, and rich and flexible enough to support the design and validation of every kind of document from the very simple to the very complex. Once RELAX NG's concepts have crossed the blood-brain barrier, you will never be able to take any other schema language very seriously again.
Roadmap

• RELAX NG goals (20 slides)
• The invoice example (9 slides)
• Patterns (20 slides)
• Datatypes (12 slides)
• The XLink example (12 slides)
• Tools (10 slides)
• XSD datatypes (16 slides)
RELAX NG GOALS
DTDs On Warp Drive

- An evolution/generalization of DTDs
- Shares the same basic paradigm
- Based on experience with SGML, XML
- Adds and subtracts features from DTDs
- DTDs can be automatically converted
Reusable Knowledge

- Experts in designing SGML and XML DTDs will find their skills transfer easily
- Design patterns commonly used in XML DTDs can be reused
- Much more mature than if based on a completely new and different paradigm
- Higher degree of confidence in its design is possible
Easy To Learn And Use

• Allows schemas to be patterned after the structure of the documents they describe
• Allows definitions to be composed from other definitions in a variety of ways
• Treats attributes and elements as uniformly as possible
Namespaces

- DTDs are namespace-blind
- RELAX NG fully supports namespaces for elements and attributes
- Namespace support is purely syntactic, not tied to one schema per namespace
- Name classes support “any name” and “any name in specified namespace”
Datatyping

- Supports pluggable simple datatype libraries
- Basic library supports strings and tokens
- Full XML Schema Part 2 datatypes available (including facets)
- New libraries can be readily designed and built as needed.
Composability

- Schema languages provide atomic objects (elements, attributes, text, typed data) and methods of composing them (sequence, repetition, choice)
- All RELAX NG atomic objects can be composed with any available method
- Improves ease of learning, use, power; decreases complexity
Closure

• RELAX NG is closed under union
  – If two schemas exist describing two document types, then a schema describing the union of the two document types is trivial to create
  – Consequently, the content model of an element can be context-dependent
Two Syntaxes, One Language

• Provides two interconvertible syntaxes:
  – an XML one for processing
  – a compact non-XML one for human authoring
• We will learn the compact syntax
• One example of the XML syntax is provided to assist in learning it
Attributes

• “Elements or attributes?”
  – Reasonable people can differ
  – Attributes are treated as much like elements as possible
• Content models include elements as well as attributes
• Attribute defaulting is not done
Non-goal: Attribute Defaulting

• Attribute defaulting can only be done by DTDs or W3C XML Schema when the value does not depend on context
• Sensible attribute defaults often depend on context (inheritance of xml:lang, e.g.)
• Attribute defaulting is trivial for transformation languages such as XSLT
Non-goal: PSVI

- RELAX NG has no post-validation infoset enhancement
- Infoset enhancement can be done as a separate layer
- Sun’s Multi-Schema Validator provides datatype information
- Separation of concerns promotes efficiency, flexibility
Annotations

- Annotations in the form of elements and attributes can be interspersed in RELAX NG schemas for various purposes:
  - DTD-style attribute defaults
  - documentation
  - embedded Java code

- Conforming RELAX NG validators ignore annotations
Mixed Content

- SGML had problems with complex mixed-content models
- XML DTDs tightly restrict mixed-content models
- RELAX NG allows character content mixed with any content model
Unordered Content

• SGML’s & operator allows unordered content models
  – A & B means ((A, B) | (B, A))

• XML DTDs removed & to reduce implementation complexity

• RELAX NG restores & with improvements
Customization

- Definitions included from another schema can be overridden
- Multiple definitions from the same or different schemas can be intelligently combined
  - as if with |
  - as if with &
A Real Standard

- Being standardized in OASIS by the RELAX NG Technical Committee
- A major component of ISO DSDL, the new Document Schema Definition Languages umbrella-standard
Non-goal: Inheritance

- Inheritance-based schemas only model single inheritance
- Modeling often requires multiple inheritance (at least for interfaces)
- Schema languages are about syntactic details, not about models
Non-goal: Identity Constraints

- Identity constraints are not supported
- Identity constraints are still a developing research area
- Different applications have different requirements from simple to complex
- Some RELAX NG tools support DTD-style semantics for ID, IDREF(S)
Non-goal: Schema Binding

• There is no standard way for a document to specify “its schema”
• Receivers often want to verify against agreed-on schemas, not sender-specified ones
• Documents may be validated against different schemas for different purposes
• The validation model takes two inputs: a document and a schema
• Just part of the XML processing issue
Pronunciation

• "Relaxing" is the standard way
• Some people say "relax en gee"
AND NOW TO RELAX!
THE INVOICE EXAMPLE
An Invoice in XML

<invoice number="640959-0" date="2002-03-12">
  <soldTo>
    <name>Reuters Health Information</name>
    <address>45 West 36th St. New York NY 10018</address>
  </soldTo>
  <shipTo>
    <name>Reuters Health Information</name>
    <address>45 West 36th St. New York NY 10018</address>
  </shipTo>
  <terms>Net 10 days</terms>
  <item ordered="6" shipped="6" unitPrice="7.812">
    Binder, D-ring, 1.5"
  </item>
  <item ordered="4" shipped="2" backOrdered="2"
    unitPrice="3.44">
    Fork, Plastic, Heavy, Medium
  </item>
</invoice>
The Invoice Schema (1)

element invoice {
    attribute number { text },
    attribute date { text },
    element soldTo {
        element name { text },
        element address { text }
    },
    element shipTo {
        element name { text },
        element address { text }
    },
}
The Invoice Schema (2)

element terms { text },
element item {
    attribute unitPrice { text },
    attribute ordered { text },
    attribute shipped { text },
    attribute backOrdered { text }?,
    text
}*
}
The XML format

```
<element name="invoice">
  <attribute name="number"/>
  <attribute name="date"/>
  <element name="soldTo">
    <element name="name">
      <text/>
    </element>
    <element name="address">
      <text/>
    </element>
  </element>
  <element name="shipTo">
    <element name="name">
      <text/>
    </element>
    <element name="address">
      <text/>
    </element>
  </element>
  <element name="terms">
    <text/>
  </element>
</element>
```

```
<element name="terms">
  <text/>
</element>
<zeroOrMore>
  <element name="item">
    <attribute name="unitPrice"/>
    <attribute name="ordered"/>
    <attribute name="shipped"/>
    <optional>
      <attribute name="backOrdered"/>
    </optional>
  </element>
</zeroOrMore>
```
Things To Note

- The structure of the schema parallels the structure of the document
- Element content models include attributes as well as child elements
- The optional attribute is marked with ?
- "text" is the equivalent of #PCDATA or CDATA
Things To Note

• Commas separate multiple components of a content model when the components appear in the given order.
• Of course, the order of attributes does not matter!
• Consequently, attributes can appear in the schema before, after, or mixed in with child elements.
Definition Form

start = element invoice {
    attribute number { text },
    attribute date { text },
    element soldTo { name-addr },
    element shipTo { name-addr },
    element terms { text }*
    element item {
        attribute ordered { text },
        attribute shipped { text },
        attribute backOrdered { text }?,
        attribute unitPrice,
        text}*
}

name-addr =
    element name { text },
    element address { text }

*
Definition Form Notes

- In definition form, there must always be a definition of start
- You refer to a rule using just its name
- The order of the rules does not matter; use whatever order makes sense to you (top-down, bottom-up, alphabetical)
- Rule names are only relevant to the schema, and never appear in the document instance
DTD-Style Definitions

start = element invoice {
    attribute number { text },
    attribute date { text },
    soldTo, shipTo, terms, item
}

soldTo = element soldTo { name-addr }
shipTo = element shipTo { name-addr }
terms = element terms { text }
item = element item { ... }
name-addr = name, address
name = element name { text }
address = element address { text }

*                        *
PATTERNS
Patterns

• Patterns are the basic building blocks of RELAX NG schemas and rules
• Some kinds of patterns can contain sub-patterns enclosed in braces ({ ... })
Element Patterns

• The form is: `element name { ... }`
• The content model (child elements and attributes) is contained within the braces
• Content models consist of one or more patterns
Attribute Patterns

• The form is: `attribute name { ... }`
• The content model is contained within the braces
• Content models consist of one or more patterns
• You can't have child elements or attributes within attributes, of course!
Attribute Patterns

• So what patterns can be inside attributes?
  – The text pattern - equivalent to CDATA
  – Datatypes (next section)
  – Literal strings in quotes:
    ```
    attribute country { "US" }
    means the country attribute must have the value US.
    ```
Element Patterns

- So what patterns can be inside elements?
  - The text pattern - equivalent to \#PCDATA
  - Datatypes (next section)
  - Literal strings in quotes:
    element country { "US" } means the country element must have the content US.
The Text Pattern

- Matches any amount of arbitrary text
- Equivalent to `#PCDATA` in elements or `CDATA` in attributes
- `text*`, `text?`, `text+` all mean the same as `text`
Namespaces

- To declare elements and attributes in namespaces, use QNames in element and attribute patterns
- Namespace prefixes are declared like this:
  
  ```
  namespace foo = "(some URI)"
  ```
- Namespace declarations must come first in the schema
Default Namespaces

- You can declare a namespace for unprefixed elements (not attributes) like this:
  
  ```
  default namespace = "(some URI)"
  ```

- If you want the default namespace to have a prefix too, use:
  
  ```
  default namespace foo = "(some URI)"
  ```
Namespaces

Here's an example:

```xml
namespace one = "http://example.com/one"
namespace two = "http://example.com/two"
default namespace = "http://example.com"
element para {
    attribute one:class { text },
    attribute two:class { text },
    element line { text }*
}
```
Choice

• Two patterns separated by | represent a choice between them; the document can match one pattern or the other, not both

• Arbitrary patterns are allowed in a choice: you can have a choice between attributes, between elements, or even between an element and an attribute!
Choice

• A useful case:
  \[
  \text{element data \{ \\
  (element id \{ \text{ text } \} \mid \\
  \text{attribute id \{ \text{ text } \}) }, \\
  \text{text} \\
  \}}
  \]

• You cannot mix , and | in one list; use parentheses to disambiguate
Choice

Enumerated values use choice like this:

```xml
<element font {
  attribute size {
    "10" | "12" | "14" | "16"
  }
}
```
Interleave

- Interleave is a cross between choice and sequence
- When patterns are combined with &, they all must appear but it can be in any order (as in SGML) …
- … or even mixed together!
Interleave

• So this schema ...
  element head {
    element meta { empty }* &
    element title { text }
  }

• ... matches a head element that has any number of meta child elements (including zero) and a required title child element *mixed in anywhere.*
Interleave

• Note: In the case of attributes, sequence and interleave are the same thing, because attributes don't have ordering

• So you can use either , or & according to what is the most convenient
Quantifiers

• You can place an *, ?, or + after any pattern to allow it to be repeated:
  – * means zero or more times
  – ? means zero or one times
  – + means one or more times

• These mean the same as in DTD content models, but can be used after any pattern, not just rule names
ANY?

- There is no built-in ANY content model, like empty for empty content models or notAllowed for forbidden models

- Here’s how it can be done:
  \[
  \text{ANY} = \text{element} \ast \{ \text{attribute} \ast \{ \text{text} \} \ast \\
  \quad \& \text{text} \& \text{ANY} \ast \\
  \}
  \]
Multiple Schemas

• `external` incorporates one pattern document into another
• `include` incorporates one set of rules into another, and allows for overriding any of the included rules by name
• Rules with identical names can also be combined by choice or by interleaving
Context Sensitivity

The first paragraph cannot have footnotes; the remainder can:

```
start = element doc { first, other* }
first = element para { text }
other = element para {
  mixed { element footnote { text }* }
}
```
Comments

• Ordinary comments begin with #
• Documentation comments begin with ## and are copied (in groups) into the XML syntax as a:documentation elements
• The a: prefix represents the namespace of the DTD Compatibility extension to RELAX NG
DATATYPES
Datatypes

• A type is a named set of values
• An datatype provides a standardized, machine-checkable representation of a type
Schema Datatypes

- DTDs have only a few datatypes for attributes and only one datatype for elements
- XML Schema provides a long, but fixed, list of datatypes
- RELAX NG can work with any datatype library, including the XSD (XML Schema Datatypes) library
RELAX NG Datatypes

- Datatype patterns are written using QNames
- This use of QNames can't be confused with QNames for elements or attributes, because those are only recognized after the words `element` and `attribute`
- The built-in datatypes `string` and `token` don’t have prefixes and are recognized by all implementations
Declaring Datatype Libraries

• A prefix is declared like this:
  datatypes lib = "(some URI)"

• Datatype library declarations must come first

• RELAX NG processors recognize a system-dependent list of datatype library URIs
Useful Datatypes

• The xsd prefix is predeclared for XML Schema Datatypes
• xsd:integer represents an integer of arbitrary length
• xsd:ID, xsd:IDREF, and xsd:IDREFS are the same as the corresponding DTD attribute types
• We'll discuss all the xsd types later.
Typed Values

- "0" and token "0" match a “0” character with possible surrounding whitespace
- string "0" matches a “0” character exactly
- xsd:integer "0" matches “0” or “00” or “000” or “-0” or ...
Mixing Datatypes

- Datatypes can't be mixed with anything in the same content model, as in:

```xml
<element foo {             # ERROR!
    xsd:int, xsd:ID,
    element bar { empty }
}
```

- Character content that represents a datatype cannot have any siblings
Mixing Datatypes

• Choices involving datatypes are fine:

```xml
<element foo { xsd:int | xsd:Name } />
<element bar { xsd:int | 
    <element baz { text } } />
```
Datatype Exceptions

• `xsd:nonNegativeInteger` and `xsd:nonPositiveInteger` are existing types
• How do we say “non-zero integer”? `xsd:integer` - `xsd:integer "0"`
• We can likewise express a token that is not a name:
  `xsd:token` - `xsd:Name`
Parameters

- Parameters restrict the values of datatypes
- Each datatype has specific parameters are legal with it
- An integer between 0 and 999 inclusive:

```xml
<xsd:integer {
    minInclusive = "0"
    maxInclusive = "999"
}
```
Lists

• List patterns specify that character content or an attribute value is to be separated by whitespace into tokens

• The pattern `list {xsd:integer*}` matches a list of zero or more whitespace-separated integers
Lists

• The pattern

\[
\text{list \{(xsd:integer, token)\}+}
\]

matches the string

"32 foo 45 bar 76 baz"
THE XLINK EXAMPLE
XLink

• A W3C Recommendation for general hyperlinking in XML documents
• Simple links are like HTML a or img elements
• Extended links specify multiple endpoints, roles, and traversal paths
• XLink is all done by attributes: any element can function in any role
The XLink Namespace

namespace xlink =
    "http://www.w3.org/1999/xlink"
XLink Attribute Rules

href = attribute xlink:href {xsd:anyURI}
role = attribute xlink:role {xsd:anyURI}
arcrole = attribute xlink:arcrole
   {xsd:anyURI}
title.att = attribute xlink:title {text}
label = attribute xlink:label {xsd:NCName}
from = attribute xlink:from {xsd: NCName}
to = attribute xlink:to {xsd: NCName}
**XLink Attribute Rules**

```python
text = attribute xlink:show
    {"new"|"replace"|"embed"|"other"|"none"}
actuate = attribute xlink:actuate
    {"onLoad"|"onRequest"|"other"|"none"}
```
Simple Links

simple = element * { 
    attribute xlink:type {"simple"}, ref?, role?, arcrole?, title.att?, show?, actuate?, anyAttr*, (anyElem | text)* 
}
Extended Links

extended = element * { 
    attribute xlink:type {"extended"},
    role?, title.att?, anyAttr*,
    (title | resource | locator
    | arc | anyElem | text)*
}
Title Elements

Description of link or endpoint:

title = element * { 
    attribute xlink:type {"title"},
    anyAttr*, (anyElem | text)*
}
Resource Elements

Local endpoints of an extended link:

```
resource = element * {
    attribute xlink:type {"resource"},
    role?, title.att?, label?,
    anyAttr*, (anyElem | text)*
}
```
Locator Elements

Remote endpoints of an extended link:

locator = element * {
  attribute xlink:type {"locator"},
  href, role?, title.att?, label?,
  anyAttr*, (title | anyElem | text)*
}
Arc Elements

Traversal paths through an extended link:

\[
\text{arc} = \text{element} \ast \{
\text{attribute xlink:type{"arc"}},
\text{arcrole}\?, \text{title.att}\?, \text{show}\?,
\text{actuate}\?, \text{from}\?, \text{to}\?, \text{anyAttr}\ast,
(\text{title} | \text{anyElem} | \text{text})\ast
\}
\]
Non-XLink Elements and Attributes

anyElem = element * { 
  anyAttr*, 
  (anyElem | text)* 
}

anyAttr = attribute * - xlink:* 
{text}
The Whole Document

start = element * { anyAttr*,
   (simple | extended | anyElem)* }
TOOLS
The Jing validator

- Written by James Clark, principal author of RELAX NG
- Java based command-line tool
  - Validates schemas
  - Validates schemas against documents
- Accepts either compact or XML syntax
- Optionally enforces DTD ID/IDREF
The Jing validator

- Also usable as a validation library within a Java program
- Provides JAXP (Sun-standard) interface
- Provides native interface
The Trang translator

- Another James Clark product
- Translates schemas:
  - Compact syntax to XML syntax
  - Either syntax to DTDs
  - In progress: either syntax to XML Schema
- Output schemas may accept superset of what the input accepts
DTDinst

- Yet another James Clark Java-based command-line tool
- Translates XML 1.0 DTDs into XML syntax, *preserving as much structure as possible*
- Can generate an XML representation of the DTD for further processing
Sun RELAX NG translator

• Translates other schema languages into XML syntax:
  – DTDs
  – RELAX Core/Namespace
  – TREX
  – Subset of XML Schema

• Does not preserve schema structure
Sun Multi-Schema Validator

• By Kohsuke KAWAGUCHI, a major RELAX NG contributor
• Validates documents (command-line or library) using schemas written in:
  – DTD syntax
  – RELAX Core/Namespace
  – TREX
  – XML Schema (subset implementation)
The Tenuto validator

• A C# implementation of validation for .NET's Common Language Runtime environment
• Supports XML syntax, XSD library
• Does not support ID/IDREF semantics
The VBRELAXNG validator

- A validator for the XML syntax written in Visual Basic 6.0
- Provides validation as an ActiveX control
- Requires MSXML 4.0 parser
The RelaxNGCC compiler

- Accepts a subset of RELAX NG (no ambiguous grammars) with annotations
- Compiles specified RELAX NG rules into Java classes
- Embedded Java code can refer to the values matched by datatype, text, and list patterns
The RelaxNGCC compiler

- The generated code requires a source of SAX events (typically a parser)
- Objects of the generated classes are data bindings for RELAX NG rules considered as types
- The killer app for RELAX NG?
Mini-roadmap

• Types (11 slides)
• Facets (5 slides)
XML Schema Datatypes

- A type is a named set of values
- An XML Schema datatype provides a standardized, machine-checkable representation of a type
- XML Schema types can be grouped:
  - numeric, date, boolean, string, misc.
Numeric Types

- Decimal types
- Floating-point types
Decimal Types

- decimal
  - integer
    - nonPositiveInteger
      - negativeInteger
    - nonNegativeInteger
      - positiveInteger
      - unsigned{Long, Int, Short, Byte}
  - long, int, short, byte
Decimal Types

- long, short, int, and byte are the same as in Java: 64, 32, 16, 8 bits
- unsignedLong, unsignedShort, unsignedInt, and unsignedByte are the obvious unsigned analogues
- All other numeric types are unbounded
Floating-point Types

• Only two floating-point types
  – float
  – double

• IEEE ranges (same as Java, all modern hardware)
Date Types

- duration
- date, time, dateTime
- gYear, gMonth, gDay, gYearMonth, gMonthDay
Date Types

• Duration
  - duration

• Single Time Interval
  - dateTime, date, gYear, gYearMonth

• Recurring Time Interval
  - time, gMonth, gDay, gMonthDay
# Date Type Examples

<table>
<thead>
<tr>
<th>Type</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>duration</td>
<td>P1D PT30M P2M</td>
</tr>
<tr>
<td>dateTime</td>
<td>2002-06-17T13:45:00</td>
</tr>
<tr>
<td>Date</td>
<td>1776-07-04</td>
</tr>
<tr>
<td>Time</td>
<td>17:05:00-05:00</td>
</tr>
<tr>
<td>gYear</td>
<td>1984</td>
</tr>
<tr>
<td>gMonth</td>
<td>--12</td>
</tr>
<tr>
<td>gDay</td>
<td>---29</td>
</tr>
<tr>
<td>gYearMonth</td>
<td>1917-11</td>
</tr>
<tr>
<td>gMonthDay</td>
<td>--09-11</td>
</tr>
</tbody>
</table>
Boolean Type

• Only two values are legal:
  – true (which can also be written 1)
  – false (which can also be written 0)
String Types

- string
  - normalizedString
- token
  - language
  - NMTOKEN(S)
  - Name
    - NCName
      - ID, IDREF(S), ENTITY(IES)
Miscellaneous Types

- Raw octet types
  - hexBinary
  - base64Binary
- anyURI
- QName
- NOTATION
Facets

• Allow the creation of new datatypes by restricting the existing ones in one or more ways
• Called params in RELAX NG
• Facets can be grouped into families applicable to datatype families:
  – length, value, pattern
  – enumeration, whiteSpace
Length Facets

• Applicable to string and miscellaneous types
• length facet gives exact length
• minLength and maxLength facets set limits; either or both may be used
• lengths of hexBinary and base64Binary types are measured in octets, not characters
Value Facets

- Applicable to numeric and date types
- `minExclusive` and `minInclusive` specify a lower bound; either but not both may be used
- `maxExclusive` and `maxInclusive` specify an upper bound; either but not both may be used
Value Facets

- `totalDigits` specifies the total number of significant digits in a decimal, integer, (non)PositiveInteger, or (non)NegativeInteger value.

- `fractionDigits` specifies the number of fractional digits in a decimal value.
Pattern Facet

• Applicable to any type
• Specifies a regular expression that the data must match
• XML Schema: If multiple pattern facets are present, the data must match at least one of them
• RELAX NG: If multiple pattern facets are present, the data must match all of them
MORE INFORMATION

http://www.relaxng.org
http://www.ccil.org/~cowan/relaxng.ppt